Intracardiac Shunt

Use of the Hydrogen-Sensitive Catheter to Clarify False Positive Diagnosis of Left-to-Right Shunt

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■ *The charts of 142 patients who had diagnostic right heart catheterization with conventional oximetry, oxygen content determinations and hydrogen electrode curve recording for left-to-right shunt were reviewed. A false positive diagnosis of surgical significance would have been made in nine patients if the hydrogen electrode had not been used. In addition, a diagnosis of left-to-right shunt could have been made at the wrong chamber level in three additional cases.*

INTRODUCTION of the hydrogen-sensitive electrode catheter by Clark and Bargeron in 1959 was a major advance in the detection of intracardiac shunts.[4] Previous methods of study such as oxygen content determinations, oximetry and nitrous oxide techniques were time-consuming, requiring multiple blood specimens, and were associated with a disturbing incidence of false positive and false negative diagnosis. Several observers have reported on the usefulness of hydrogen curves in establishing the presence of left-to-right shunts when conventional methods were inconclusive.[5,6,12] Shunts as small as 50 ml per minute are detectable by hydrogen study.[2]

Our interest in this subject concerns primarily the presence of false positive diagnosis of intracardiac shunts as established by standard methods of study. Dye dilution curves have been of value in clarifying this dilemma when the two-catheter technique is employed. However, dye curves require withdrawal of multiple specimens of blood and the procedure is distinctly more complex than the recording of hydrogen curves.

For the past three and a half years in our laboratory hydrogen curves have been recorded routinely along with conventional right heart techniques. This communication is a report of our experience with cases in which a false diagnosis of intracardiac shunt would have been made had it been based on conventional blood analysis (oxygen content or double scale oximetry or both).

Methods

The charts of 142 patients who had conventional right heart catheterization at the San Diego County Heart Center were reviewed. All of them had combined oxygen content determination and/or double scale oximetry in conjunction with hydrogen curve recordings.* Blood specimens were drawn anerobically from all heart chambers and analyzed according to the method of Van Slyke and Neal.[11] Duplicate readings with checks to within 0.2 volume per cent were required on all specimens. The average number of specimens was

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*U.S. Catheter Company—Platinum Electrode Catheter No. 353-PT.

TABLE 1.—*Clinical and Cardiac Catheterization Data in Nine*

Case No.	*Clinical Findings*	*Electrocardiogram*	*Chest X-Ray*
1	9-year-old boy with heart murmur since infancy. Asymptomatic. Physical findings of slight right precordial bulge. Grade IV systolic ejection murmur 2nd left intercostal space with a thrill 2nd left intercostal space. 2nd sound in pulmonic area louder or equals 2nd sound aortic area.	Right ventricular hypertrophy.	Prominent pulmonary artery with normal lung vascularity.
2	51-year-old woman with history of progressive dyspnea and cyanosis of hands and lips of 18 months' duration. Physical findings of a prominent jugular A wave, positive hepatojugular reflux, right ventricular lift, pulmonary closure tap, and murmur of tricuspid insufficiency.	Right ventricular hypertrophy, right atrial hypertrophy and myocardial ischemia.	Progressive cardiomegaly, full main pulmonary artery, diminished vascularity peripherally in lung fields.
3	3-year-old boy with heart murmur since birth. Grade III pansystolic murmur lower left sternal border.	Normal.	Left ventricular dilatation.
4	11-year-old boy with heart murmur detected on routine physical examination at age 10. Auscultation revealed in grade II systolic murmur at left sternal border at base of heart radiating to left infraclavicular area.	Normal.	Possible right heart enlargement with normal pulmonary vasculature.
5	22-year-old woman with heart murmur detected on routine examination at age 20. Auscultation received a pansystolic murmur at left sternal border at apex radiating to left axilla.	Normal.	Normal.
6	13-year-old boy with heart murmur detected at age 10 on routine physical examination. Auscultation revealed a grade III systolic ejection murmur at left sternal border at 3rd intercostal space with poor radiation to apex and base.	Normal.	Normal.
7	20-year-old man with history of heart murmur since age 10. Physical examination revealed a slight pectus excavatum and a grade III high-pitched systolic murmur at the left sternal border with a fixed and split P2.	Incomplete right bundle branch block.	Increased pulmonary vasculature with intrinsic pulsation of the mid one-third of the right lung.
8	20-year-old woman with heart murmur heard on routine physical examination. Auscultation revealed grade III systolic ejection murmur 2nd left intercostal space with a thrill and early systolic ejection click.	Right atrial and right ventricular hypertrophy.	Dilatation of the pulmonary artery.
9	40-year-old man with history of closure of ventricular septal defect at age 28. Auscultation revealed widespread precordial systolic ejection murmur maximum at 3rd left intercostal space. A widely split P2 and a diastolic decrescendo murmur at left sternal border.	Right ventricular hypertrophy.	Right ventricular enlargement.

†Oximetry and Van Slyke determinations on same specimen.
Abbreviations: SVC=superior vena cava; RA=right atrium; RV=right ventricle; PA=pulmonary artery.

TABLE 2.—*Data on Three Cases in Which Shunt Could Have Been Diagnosed*

Case No.	*Clinical Findings*	*Electrocardiogram*	*Chest X-Ray*
10	7-year-old boy with heart murmur since birth. Auscultation revealed grade III pansystolic murmur lower left sternal border with associated thrill.	Normal.	Normal.
11	21-year-old man with heart murmur since infancy. Auscultation revealed grade II systolic murmur 2nd left intercostal space without a thrill.	Normal.	Normal.
12	18-year-old boy with heart murmur since birth. Auscultation revealed an apical pansystolic murmur with thrill at the 3rd left intercostal space.	Normal.	Normal.

*Proved at operation.
†Oximetry and Van Slyke determinations on same specimen.
Abbreviations: SVC=superior vena cava; RA=right atrium; RV=right ventricle; PA=pulmonary artery.

Cases with Clear-Cut Step-up in Saturation or Oxygen Content

Hydrogen Data				Catheterization Data: †Oxygen Per Cent Saturation				Catheterization Data: †Van Slyke in Volume Per Cent				
SVC	RA	RV	PA	SVC	RA	RV	PA	SVC	RA	RV	PA	Diagnosis
Neg	Neg	Neg	Neg	73.0	78.0	77.3	80.5	11.74	12.50	12.43	12.94	Moderate pulmonary valve stenosis with 38 mm Hg gradient.
Neg	Neg	Neg	Neg	50.3	58.8	61.0	60.0	9.27	10.95	11.28	11.05	Primary pulmonary hypertension with pulmonary artery pressure of 100 mm Hg.
Neg	Neg	Neg	Neg	73.8	75.6	81.7	79.0	10.38	10.60	11.55	11.20	Minimal pulmonary stenosis with a 20 mm Hg gradient at pulmonic valve.
Neg	Neg	Neg	Neg	70.0	75.4	75.0	80.0	11.70	12.60	12.60	13.35	Minimal pulmonary stenosis with 20 mm Hg gradient at pulmonic valve.
Neg	Neg	Neg	Neg	64.2	70.0	69.5	70.8	12.85	14.01	14.00	14.25	Normal right heart study.
Neg	Neg	Neg	Neg	65.2	73.2	70.5	70.9	11.30	12.75	12.30	12.38	Minimal pulmonary stenosis with 20 mm Hg gradient at pulmonic valve.
Neg	Neg	Neg	Neg	54.0	67.0	66.2	64.3	14.25	14.32	14.08	14.12	Normal right heart study.
Neg	Neg	Neg	Neg	60.8	66.0	67.0	68.0	13.99	14.88	15.15	15.20	Moderate pulmonary valve stenosis with a 73 mm Hg gradient at pulmonic valve.
Neg	Neg	Neg	Neg	61.0	70.2	71.2	71.7	13.60	14.23	14.81	14.75	Minimal pulmonary valve stenosis with 25 mm Hg gradient at pulmonic valve.

at Wrong Chamber Level Without Use of Hydrogen-Sensitive Catheter

Hydrogen Data				Catheterization Data: †Oxygen Per Cent Saturation				Catheterization Data: †Van Slyke in Volume Per Cent				
SVC	RA	RV	PA	SVC	RA	RV	PA	SVC	RA	RV	PA	Diagnosis
Neg	Neg	Pos	Pos	61.0	70.8	69.7	69.0	11.84	13.94	13.08	13.09	Ventricular septal defect.
Neg	Pos	Pos	Pos	66.0	73.1	84.0	84.2	13.15	14.60	16.80	16.78	Atrial septal defect.*
Neg	Neg	Pos	Pos	62.5	83.1	81.8	81.0	10.53	14.68	13.61	13.65	Ventricular septal defect.

13 per patient and they were drawn from the various right heart chambers, vena cava and main pulmonary artery. Double scale oximetry was performed by passing blood through a Waters Double Scale Oximeter Model X-70 A, readings being obtained during flow and no flow. Using this method, duplicate checks to within 1 per cent are obtained. A left-to-right shunt was considered to be present when a step-up of 1.5 volumes per cent occurred between superior vena cava and right atrium or 1.0 volumes per cent change between the right atrium and right ventricle or right ventricle and pulmonary artery. In a similar fashion an 8 per cent step-up on oximetry was considered compatible with a shunt at the atrial level, and a 5 per cent step-up was taken as evidence of a shunt at the ventricular or pulmonary artery levels.

Hydrogen curves were recorded in the main pulmonary artery, right ventricle, right atrium, superior vena cava and the innominate junction. Three curves were recorded at each site. Curves were recorded on a D.R.-8 rcorder* with a paper speed of 25 mm per second. Inspiration was carefully noted on the record and the time interval from beginning of inspiration to deviation of the hydrogen curve from baseline was recorded. A left-to-right shunt was considered to be present when hydrogen curve deflection occurred in four seconds or less.

Results

In 22 of the 142 cases reviewed, the criteria for the presence of a left-to-right shunt were exceeded although hydrogen curves remained negative. Critical analysis of the 22 cases would permit exclusion of 10 cases on the basis of an isolated step-up not borne out on multiple specimens. In nine cases clear-cut step-up in saturation or in oxygen content were demonstrated on multiple samples in the face of negative hydrogen curves. It should also be noted that the clinical findings, electrocardiographic, phonocardiographic and radiographic features were also considered and supported the results obtained by hydrogen techniques in each case. Data on these cases are presented in Table 1.

In three cases positive hydrogen curves for a left-to-right shunt were confirmed by conventional technique, but in those three cases the shunt could have been diagnosed at the wrong chamber level if only the conventional technique had been used (Table 2).

*Electronics for Medicine—White Plains, N.Y. DC amplifier, Model PHD-2.

Discussion

The introduction of the platinum-tipped hydrogen-sensitive electrode by Clark and Bargeron has constituted a major milestone in the study of intracardiac shunts. Previous reports[7,8] have demonstrated the need for improved techniques in detecting left-to-right shunts and suggested the use of the nitrous oxide test. Still others advocated helium-oxygen,[1] krypton 85 inhalation test[3] or the use of various indicator dilution curves[10] as improved methods over the determination of oxygen content differences.

Hydrogen-sensitive electrode techniques have proved extremely reliable in the detection of extremely small shunts and the simplicity of the method makes it applicable in most cases. Vogel[13] described a simplified bedside method for detecting intracardiac shunts utilizing an electrode catheter introduced percutaneously. Skelton and Corday[9] also employed the hydrogen electrode for demonstrating aortic and tricuspid regurgitation. Our prime interest in reviewing this series was not to demonstrate its efficiency in clarifying the false negative studies obtained by oxygen content determination, but rather to point up its value in avoiding the false positive diagnosis sometimes reached by conventional studies. False positive diagnosis occurred in 8.4 percent of the cases reviewed, which could have resulted in needless operation or repeated catheterization because of variance with the clinical observations.

It is our belief that the hydrogen-sensitive electrode should be routinely included in right heart catheterization in any case in which there is even remote possibility of a left-to-right shunt.

REFERENCES

1. Amplatz, Kr., Wang, Y., and Adams, P. Jr.: Helium-oxygen inhalation test. A simple test for identification of small left-to-right shunts (Abst.), Circulation, 24:877, 1961.

2. Bargeron, L. M. Jr., Clark, Leland C., and McArthur, Katrina T.: The detection of intracardiac shunts by the use of intravascular potentiometric electrodes, Am. J. of Dis. of Children, vol. 100, p. 82, 1960.

3. Braunwald, E., Goldblatt, A., Long, R. T. L., and Morrow, A. G.: The krypton 85 inhalation test for the detection of left-to-right shunts, Brit. Heart J., 24:47, 1962.

4. Clark, L. C. Jr., and Bargeron, L. M. Jr.: Left-to-right shunt detection by an intravascular electrode with hydrogen indicator, Science, 130:709, 1959.

5. Hurlburt, J. C., Harris, C. W., Rackley, C. E., Floyd, W. L., and Orgain, E. S.: Hydrogen sensitive,

platinum-tipped electrode in the diagnosis of left-to-right shunts, Am. J. Cardiol., 15:680, 1965.

6. Hyman, A. L., Hyman, E. S., Quiroz, A. C., and Gantt, J. R.: Hydrogen-platinum electrode system in detection of intravascular shunts, Am. Heart J., 61:53, 1961.

7. Morrow, A. G., Sanders, R. J., and Braunwald, E.: The nitrous oxide test. An improved method for the detection of left-to-right shunts, Circulation, 17:284, 1958.

8. Sanders, R. J., Cooper, T., and Morrow, A. G.: An evaluation of the nitrous oxide method for the quantification of left-to-right shunts, Circulation, 19:898, 1959.

9. Skelton, R. B. T., and Corday, E.: Hydrogen electrode technique for demonstrating experimental insufficiency of the aortic and tricuspid valve, (Abst.), Circulation, 26:787, 1962.

10. Symposium on Diagnostic Applications of Indicator Dilution Techniques, Proc. Staff Meet., Mayo Clin., 32:463, 1957.

11. Van Slyke, D. D., and Neill, J. M.: The determinations of gases in the blood and other solutions by vacuum extraction and manometric measurement, J. Biol. Chem., 61:523, 1964.

12. Vogel, J. H. K., Grover, R. F., and Blount, S. G.: Detection of small intracardiac shunts with the hydrogen electrode. A highly sensitive and simple technique, Am. Heart J., 64:13, 1962.

13. Vogel, J. H. K., Averill, K. H., Tabari, K., and Blount, S. G.: Detection of intracardiac shunts with the platinum electrode, using a simplified percutaneous approach, Am. Heart J., 67:610, 1964.